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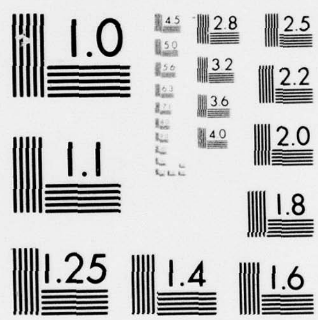

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AN ANALYSIS OF THE VIBRATION LEVELS ON THE BRIDGE OF H.M.A.S. LABUAN IN ROUGH SEAS

G. Long and P. A. Farrell

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AN ANALYSIS OF THE VIBRATION LEVELS ON THE BRIDGE OF H.M.A.S. LABUAN IN ROUGH SEAS

by

G. Long and P. A. Farrell

Summary

The fore-and-aft vibration levels occurring on the bridge of H.M.A.S. Labuan in rough seas have been recorded and analysed. The results for the frequency range 0 - 10 Hz are presented.

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16. ABSTRACT:

The fore-and-aft vibration levels occurring on the bridge of H.M.A.S. Labuan in rough seas, have been recorded and analysed. The results for the frequency range 0 - 10 Hz are presented.

CONTENTS

1. INTRODUCTION

To provide design data for the vibration absorber described in reference 1 a series of vibration measurements were made on H.M.A.S. Labuan in rough seas. These measurements were aimed at measuring the ship's response in the two-node vertical bending mode at approximately 3.2 Hz. The data have been analysed and the power spectral density and probability density functions have been obtained in the frequency range 0 - 10 Hz. In addition the Random Decrement method (reference 2) has been used to obtain the time history of the ship's impulse response to wave motion.

These data should be of use in specifying the vibration environment on the ship for instrumentation and equipment design.

2. DETAILS OF MEASUREMENTS AND RECORDING

The vibration was measured by two servo-accelerometers mounted on the bridge floor with their sensitive axis in the fore-and-aft direction (see Fig. 1). The accelerometer signals were filtered by low-pass filters set to 10 Hz. cut-off frequency and digitised at a rate of 20 samples per second. These digital signals were then recorded on two small magnetic tape recorders.

By locating the accelerometers on the bridge in the fore-and-aft direction, the response to vertical vibration in the three-node mode was minimised. As shown in Fig. 2B the bridge is close to an anti-node of the three-node mode and is therefore subjected only to vertical vibration from deformation in this mode. Fig. 2A however shows that the bridge is almost vertically above a node of the two-node mode and hence will be subjected to a fore-and-aft motion as a result of its distance from the point of rotation in this region.

Several records of vibration were made in various sea conditions. The record analysed was made in conditions which were so severe that the captain decided to turn back and run before the waves. (Estimated sea state 4, wind force 7, speed 10 knots.)

3. METHOD OF ANALYSIS

The vibration data are essentially random and consequently the normal way to describe them is by means of the power spectral density and probability density functions. Both these functions were derived by direct analysis of the data on a digital computer

and are presented in figures 3 and 4. The R.M.S. acceleration level in the frequency range 0 - 10 Hz is 0.067 g (N.B. 'g' refers to the gravitational acceleration).

To obtain the Random Decrement signatures the data were digitally filtered to separate the responses in the rigid body pitch mode and the two-node mode. Two sets of data were thus obtained, each of which contained the random response of the ship in discrete frequency ranges. These sets were integrated twice to convert from acceleration to displacement response and then averaged to obtain the Random Decrement signatures. The resultant signatures are shown in Figs. 6A and 6B. These provide an estimate of the displacement impulse response of the ship in the rigid body pitch mode and the two-node vertical bending mode respectively. From these signatures the natural frequencies and dampings of the responses may be estimated directly.

4. DISCUSSION OF RESULTS

In figure 3 the power spectral density of the vibration is plotted as a function of frequency. Three peaks in the response occur at 0.2 Hz, 3.25 Hz and 6.5 Hz corresponding to the rigid body pitch, two-node vertical bending and three-node vertical bending modes respectively. As mentioned previously the last response is small because of the method of mounting the transducer.

The response in the two-node mode at any point on the ship may be estimated from the measured response by using figure 2. In this mode of vibration the fore-and-aft amplitude of the bridge floor is equal to the vertical amplitude of the ship at frame 70. This fact is sufficient to allow other amplitudes to be obtained by simple scaling from this figure. Based on this mode shape, the maximum vertical acceleration on the ship in the two-node mode would occur at the bow and the level would be approximately 1.7 times that measured on the bridge floor.

From figure 3 the R.M.S. acceleration experienced in the frequency range 3 - 3.5 Hz is approximately 0.024 g. Since the vibration is approximately Gaussian, the vibration level would be expected to be within ± 0.072 g. (i.e. ± 3 standard deviations from the mean) for 99.73% of the time. In reference 3 this vibration amplitude is classified as extremely uncomfortable and of sufficient level to cause

structural damage in regions of high stress concentrations.

The probability density function of thes data is shown in Fig. 4. The form of the curve is reasonably close to Gaussian as would be expected. These results are based on a vibration record of approximately 60 minutes duration.

In Fig. 5 a time-history of the acceleration is reproduced. This includes the maximum vibration level recorded during the test and shows the rigid body oscillation and the long decay of the two-node mode of vibration. The maximum acceleration in the two-node mode is approximately $\pm$ 0.6 g on the bridge floor or $\pm$ 1 g at the bow. This corresponds to an amplitude of $\pm$ 23.5 mm ($\pm$ .92 ins).

Figs. 6A and 6B show the transient response of the ship in the rigid body pitch and two-node modes determined by the Random Decrement method. In both figures it is apparent that the decay rates depend on amplitude. For the higher frequency mode the damping rate appears to increase with increase in amplitude. The reverse is true for the rigid body mode. It is a simple matter to estimate frequencies and dampings from these figures.

5. CONCLUSIONS

The vibration levels occurring in rough seas in the rigid body pitch and two-node vertical bending modes of H.M.A.S. Labuan have been analysed. The data obtained should be of use in specifying the vibration environment on the ship in the frequency range 0 - 10 Hz.

REFERENCES

1. G. Long and P. A. Farrell	The design and installation of a damped vibration absorber A.R.L. Structures Note 440
2. Cole, H. A.	On-line failure detection and damping measurement of aerospace structures by Random Decrement signatures NASA CR-2205 1973.
3. Todd, F. H.	Ship hull vibration Edward Arnold (Publishers) Ltd., 1961.

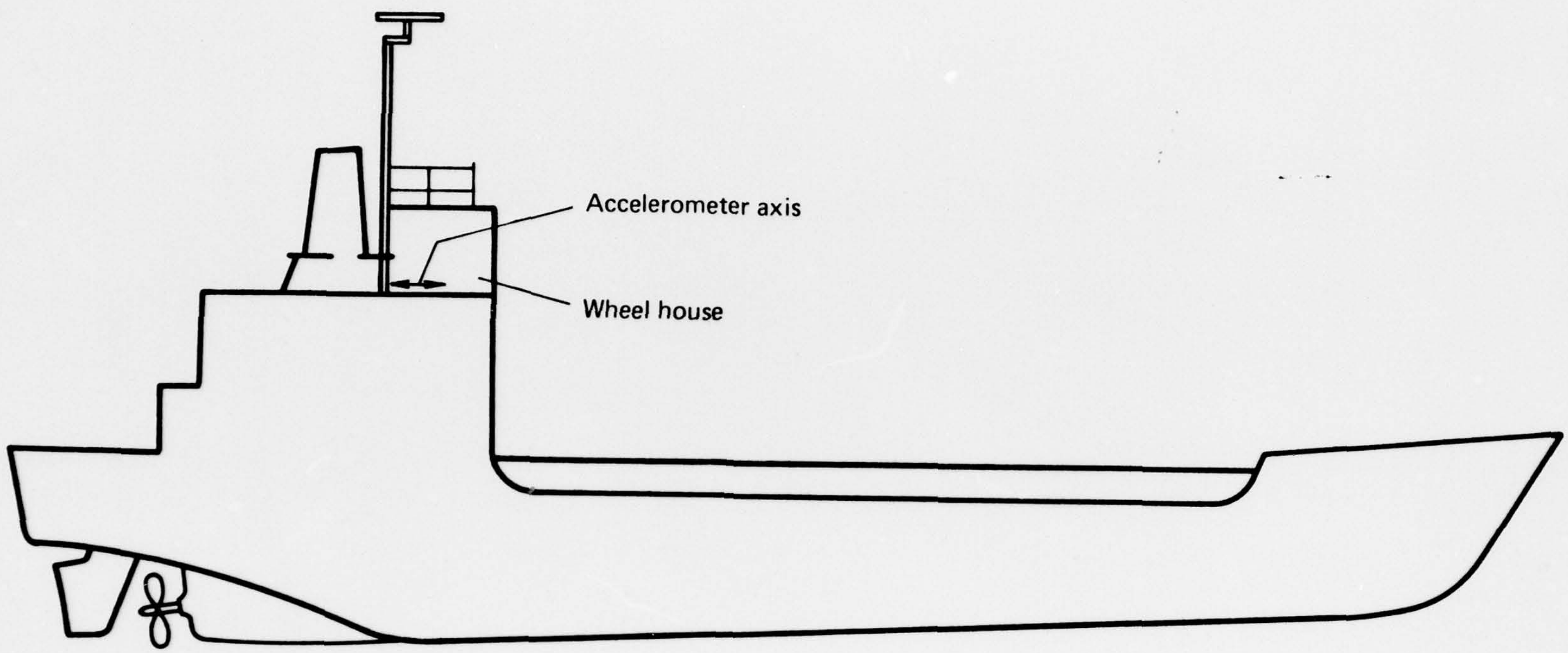

FIG. 1 ACCELEROMETER POSITION ON SHIP

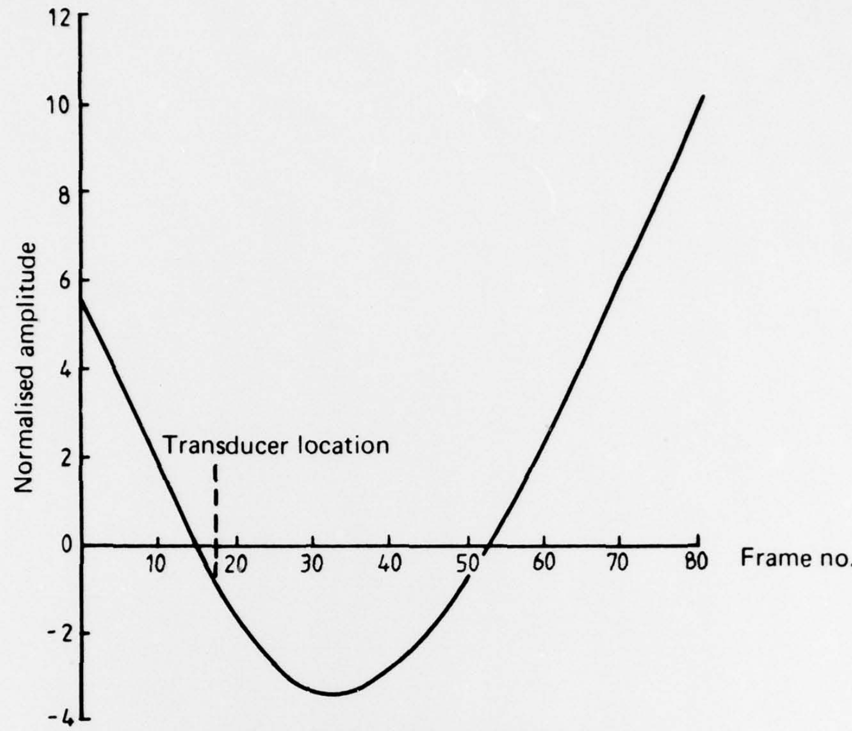

FIG. 2A MEASURED TWO-NODE MODE

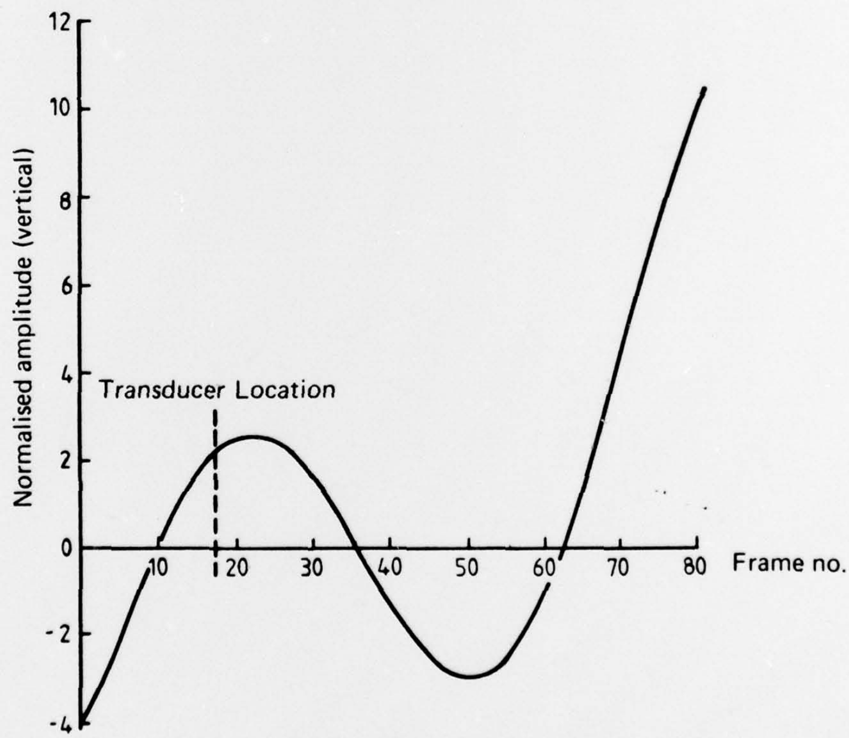

FIG. 2B MEASURED THREE-NODE MODE

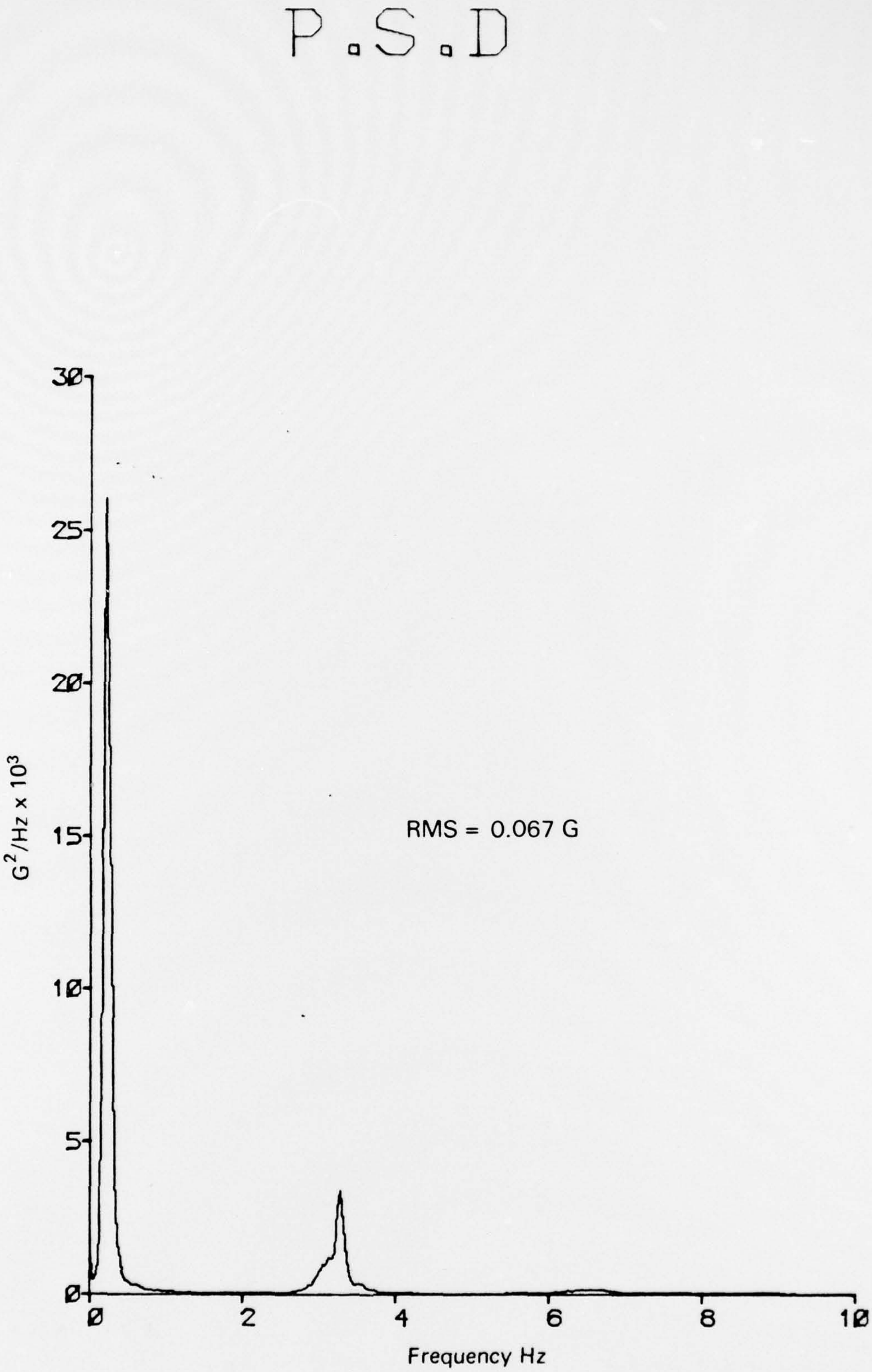

FIG. 3 POWER SPECTRAL DENSITY OF RESPONSE

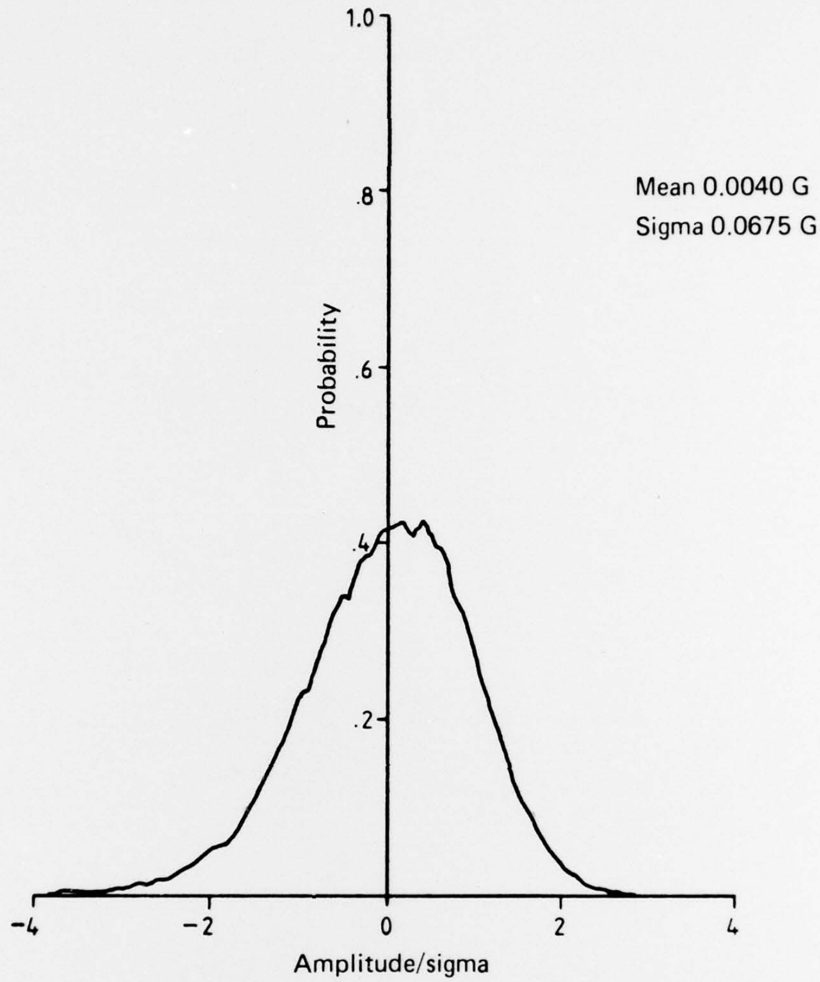

FIG. 4 PROBABILITY DENSITY FUNCTION OF RESPONSE

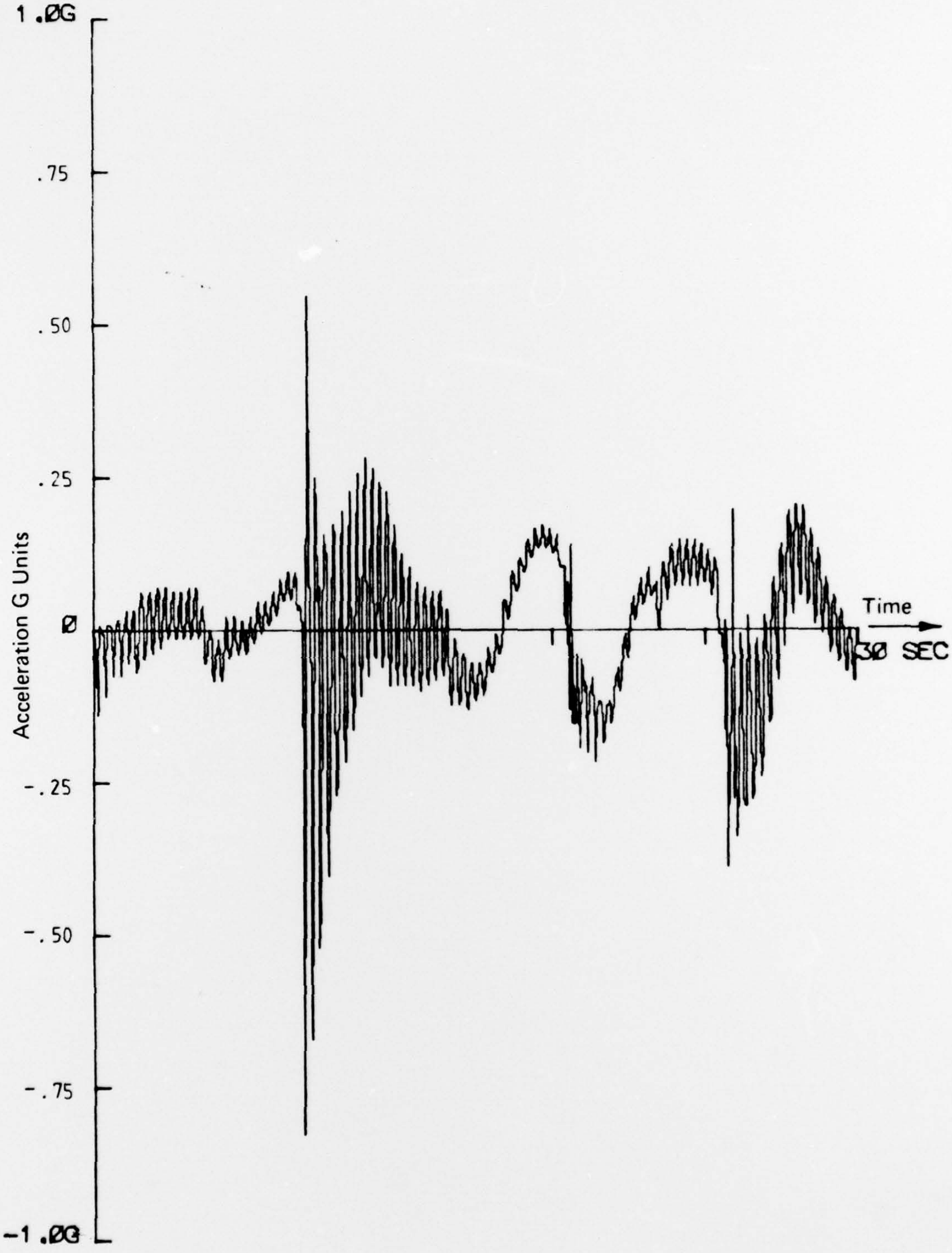

FIG. 5 TIME HISTORY OF ACCELERATION

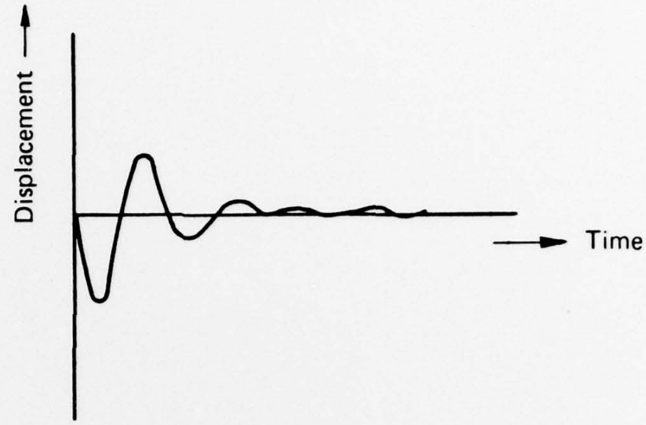

FIG. 6A RANDOM DECREMENT SIGNATURE OF RIGID BODY MODE

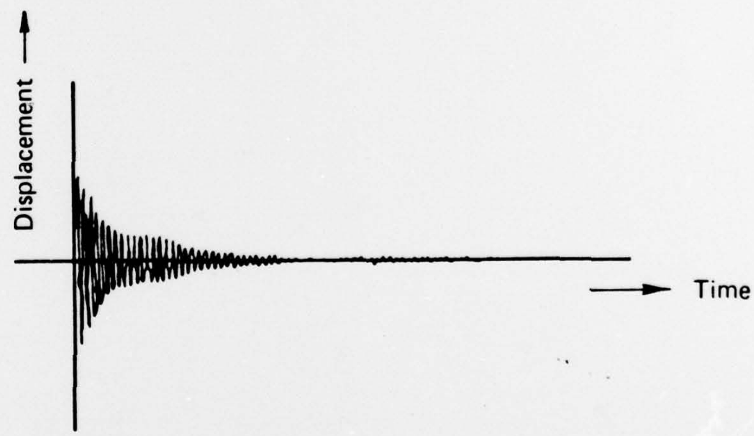

FIG. 6B RANDOM DECREMENT SIGNATURE OF TWO-NODE MODE

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